Millions of stacked

Traditionally and physically, glass and spherical shapes are the preferred parameters when designing and manufacturing lenses. But miniaturization, imaging quality improvement and price-reducing mass production demand for aspherics as forms and plastics as materials. Examples of this trend are the optics in modern mobile phones, which are able to take and transmit pictures and video films. Thanks to its unique WaferOptics® process, Anteryon in Eindhoven, the Netherlands, succeeded in producing such optical systems in huge quantities at challenging cost prices.

• *Frans Zuurveen* •

Anteryon started as a spin-off from Philips Electronics and excels in the ins and outs of replication technologies. These skills originate from the design and production of lenses for optical pick-ups for reading compact discs. This activity was the logical consequence of the successful introduction of the Compact Disc Digital Audio system by Philips and Sony at the beginning of the eighties. The replication technology made it possible to compensate image forming errors that are inherent to spherically formed lenses. The processes from those early CD days are still in use in the Anteryon clean rooms, see Figures 1 and 2.

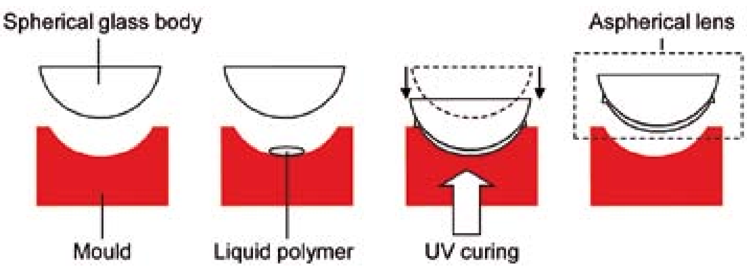

Figure 1. The Anteryon single-lens replication process for the production of aspherics.

Figure 2. One of the Anteryon clean rooms in Eindhoven.

lenses a week

Anteryon – with a staffing of about 120 persons – has many optical machining abilities in house, including sand blasting, grinding, lapping and etching. And as a consequence of the replication process, Anteryon is an expert in the chemistry of UV hardening glues and UV curing resins. Of course, it also masters physical technologies for the deposition of special coatings, like sputtering and evaporation. Moreover, the WaferOptics process requires thorough knowledge of reproduction and aligment procedures. And last but not least, Anteryon is able to predict whether glues and resins adhere to a surface or – reversely – easily loosen from a substrate.

The basic process for aspherics

Figure 1 shows how aspherical lenses are born by correcting spherical glass lenses. In a one-by-one replication process a one-sided flat spherical glass body is being pressed into a droplet of liquid polymer in a UV transparent mould that, negatively, has the aspherical form desired. After that, UV light cures the resin. The crux of the Anteryon replication process is the exact transfer of the lens shape in the mould to the glass surface, thereby ensuring adhesion of the hardened resin to the glass and allowing release of the product from the mould. In other words: the glass body with a thin layer of polymer that gives the glass lens the optical properties necessary to function in the CD and DVD reading process, can easily be taken out of the mould.

Of course, realizing the right aspherical form is an essential condition, in the above-mentioned procedure as well as in the manufacturing process to be described next. Anteryon's optical experts therefore calculate the mathematical data with appropriate computer programs, resulting in the right image of a diode laser on the memory disc. Or, in the WaferOptics case, to find the required characteristics of one element in an optical objective system, i.e. for mobile phones. These mathematical data are translated into a master model. Unfortunately, details of the Anteryon mastering method are not available because the master process tricks are regarded as company secrets.

WaferOptics

Figure 3 shows an 8-inch glass wafer (in future 12-inch wafers will be used) with about 4,000 lenses for objectives to be used in – for example, Nokia – mobile phones. On one hand, such objectives must be very small, on the other hand, they have to comply with stringent optical requirements. This means that mobile phone objectives consist of an assembly of several, nearly always aspherical, elements; see Figure 4.

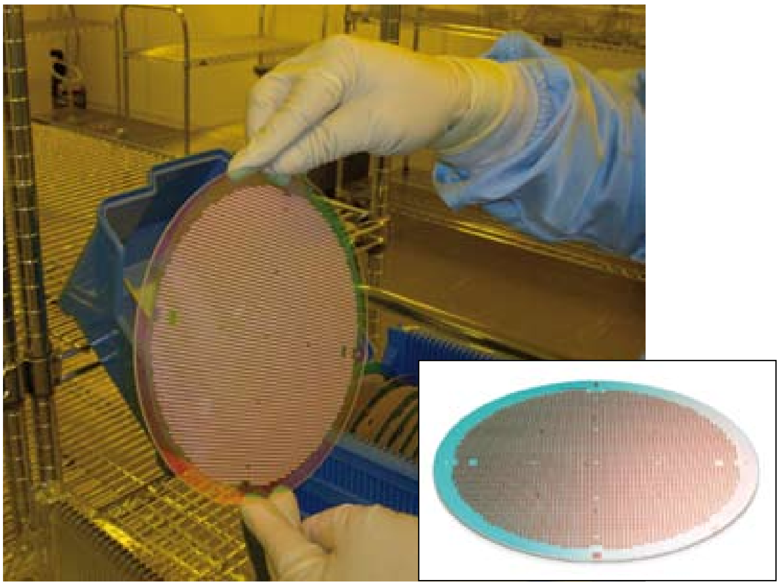

Figure 3. 8-inch glass wafer with about 4,000 lenses for mobile phone objectives.

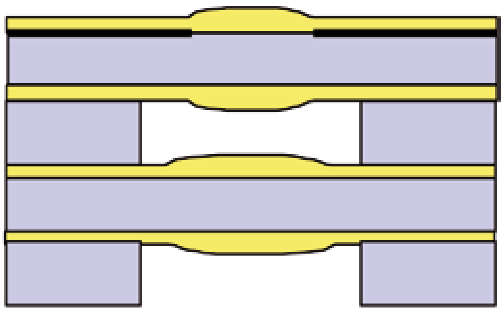

Figure 4. Thanks to the WaferOptics process, a mobile phone objective combines several aspherical elements.

The WaferOptics process resembles IC manufacturing processes, with the difference that UV- and visible light-transparent glass with a thickness of 0.3 to 1.5 mm forms the substrate and not – still thinner – monocrystalline

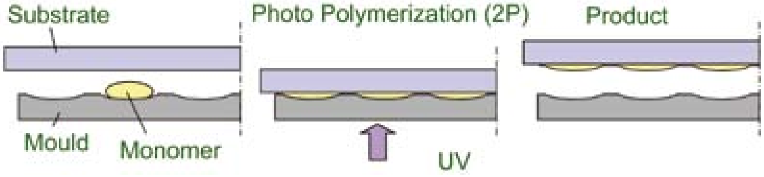

Figure 5. The process starts with the replication and photo polymerization of lots of optical elements at one side of a glass wafer.

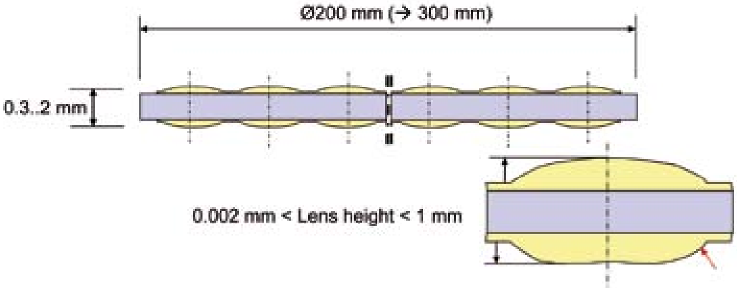

Figure 6. After turning the wafer around, a set of elements is applied to the other side of the wafer.

silicon. Figure 5 shows the replication and photo polymerization process for a wafer with a set of one-sided optical elements, each being > 20 µm thick. Then the wafer is turned around, after which a set of elements for the other side is applied, see Figure 6. Here again, control of the adhering or releasing properties of resin and surface is essential for a successful manufacturing process.

Then sets of optical systems are realized by combining one or more spacer plates in glass with one or two glass wafers with optical elements in resin at both sides. By a powder blasting process the spacer plates have been provided with diaphragms beforehand. UV curing glue is used to connect wafers and plates. Finally, the individual optical systems are separated by dicing with a diamond saw, which results in the products depicted in Figures 7 and 8.

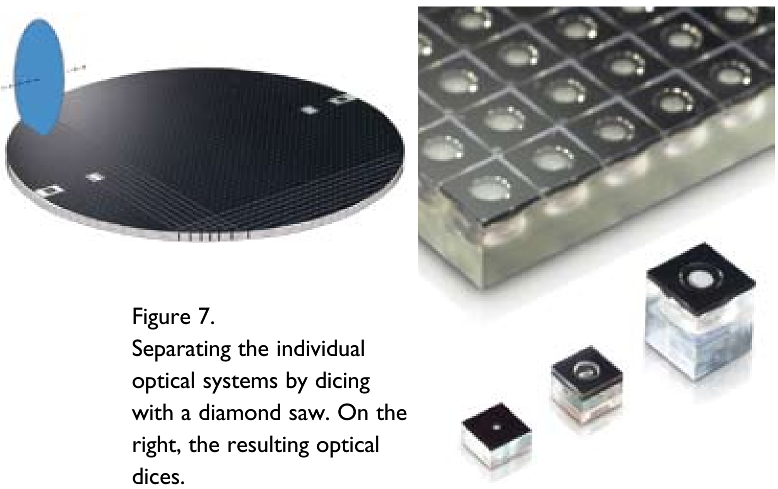

Figure 7.
Separating the individual optical systems by dicing with a diamond saw. On the right, the resulting optical dices.

Figure 8. Optical dices are real precision products.

The WaferOptics process differs from the single-lens process in the huge quantity of the same – mostly aspherical – forms in one wafer-sized mould. Anteryon produces such moulds with an in-house designed highly accurate machine that resembles an ASML wafer stepper in many respects. The machine multiplies the lens shape in UV sensitive resin on an appropriate substrate. After resin curing the acquired product can directly be used as a tool for producing optical wafers or – when mass production is the case – as a mastering tool for daughter tools. This choice determines whether the basic model has to have a positive or negative form.

Precision aligment

It will be clear that manufacturing a precision optical product as shown in Figure 8 requires the utmost precision in aligning the elements at two sides of a glass substrate, and in aligning two (or more) substrates mutually. Therefore tools and substrates are provided with optical aligning marks comparable with the ones used in IC wafer steppers. The foregoing applies to alignment in the x,y-plane, but optical properties also depend on the position accuracy of the various elements in the z-direction. This means that control of the thickness of glue layers is very important too.

How these precision demands are being fulfilled in the Anteryon clean rooms, again has to stay in the haze of company secrets. But citing some of the tolerances may give an idea of the problems Anteryon had to solve before WaferOptics products could be produced with today's yield of 95% after individual MTF inspection in Eindhoven. (MTF stands for Modular Transfer Function, a key parameter that determines the imaging quality of the lens stack.) The concentricity of the various elements in one lens stack is better than 5 µm, roadmapped to below 2 µm. The total thickness variation is smaller than 10 µm, roadmapped to 3 µm. The shape variation of each lens amounts to 100 nm RMS, roadmapped to below 50 nm.

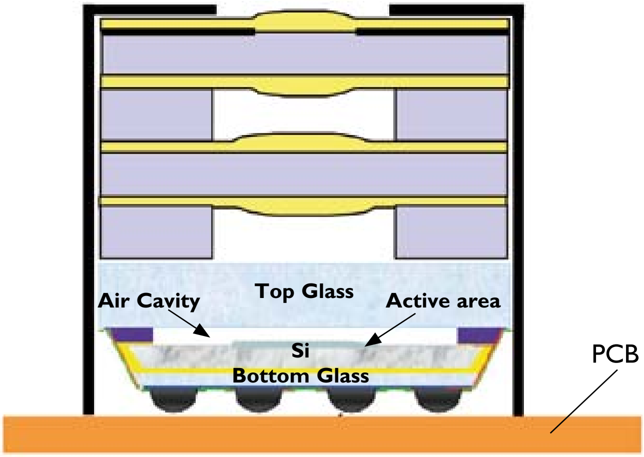

Figure 9. After being provided with a protective cap, the optical dices must be integrated with a CMOS sensor to make them suitable for surface mounting on a PCB.

The absolute position accuracy of one stack on a wafer assembly is better than 5 µm, roadmapped 1 µm.

SMD product

The stacked objective lens of Figures 7 and 8 is not the finished product. It has to be integrated with an optical CMOS sensor and thereafter made suitable for surface mounting. So it becomes an SMD, Surface Mounted Device; see Figure 9.

The stacked Anteryon lenses are quality controlled in Eindhoven, after which they are transported to China for the mounting of a protective top cap. Integration of the lens stacks with packaged image sensors occurs at the camera module assembly plant. There, the customer has to choose from a variety of sensor packaging solutions that can provide the electrical contacts between the sensor and the underlying soldering contacts. Finally, the units are put into casings that comply with the customer's SMD machines for producing PCBs for mobile phones. Figure 10 shows the size reduction of these optical units for mobile phones when compared with the products from earlier generations.

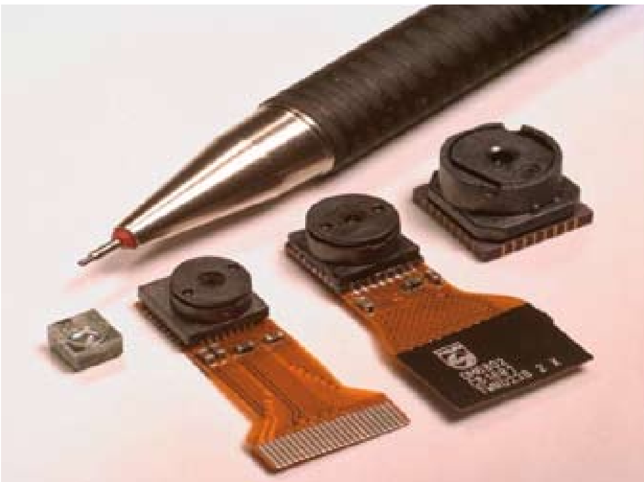

Figure 10. Size reduction of optical units for mobile phones during subsequent generations.

Figure 11. The Anteryon production programme includes a wide range, from sub-millimeter miniature lenses for Blu-ray players to large glass prisms.

MEMSland

The foregoing description of the successful WaferOptics process for optical units in mobile phones is only part of the Anteryon story. The company also produces many other optical parts, see Figure 11, from large glass prisms to submillimeter miniature lenses for Blu-ray players.

New challenges showed up in the MEMSland project, in which many partners – besides Anteryon, also Philips, NXP, TNO, Boschman and the universities of technology of Eindhoven and Delft – cooperated to find practical solutions for integration of micromechanics, electronics and optics. MEMSland was one of the largest programmes under the flag of the Point-One innovation programme for nano-electronics, embedded systems and mechatronics; see the February issue of Mikroniek for a report on the MEMSland Closing Symposium.

To conclude

Manufacturing optical systems for mobile phones in huge quantities has much to do with a passion for precision. Recently, Anteryon celebrated the delivery of the 25,000,000th optical unit of one type within a time span of one and a half year. This milestone could be achieved due to the enthusiasm of the complete Anteryon crew – which provides a sunny outlook on volume production of other types of lens stacks for new customers.

Author's note

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Information

www.anteryon.com